

## **Project Name: Morphometric change in morphological variability through time in the Ediacaran fossil, *Pteridinium***

### **Project Report**

#### **Project goals and Hypothesis**

This project aim was to measure the range of morphologic variability through time in the Ediacaran fossil, *Pteridinium*, from different collections and sites in Namibia, North Carolina, and the Peabody Museum at Yale University. A summary of my hypothesis would be that morphologic variability in *Pteridinium* (fig 1), will decrease through time, reflecting increasing stabilizing selection till the Cambrian. *Pteridinium* is a quilted, triple-bladed organism, which lacks ready categorization within modern taxonomic schemes, by examining the type of morphological changes taking place in *Pteridinium* through time, it will be possible for greater accuracy in dating Ediacarans with uncertain temporal affinities, while possibly being able to better place them into a more specific paleo-biogeographic context.

#### **Methods**

The hypothesis was tested through the use of geometric morphometric analysis of *Pteridinium*. This involved making detailed measurements of both original and cast material from the selected sites, as well as taking high-resolution pictures of each specimen from multiple angles. Morphological analysis uses recognizable and repeatable features of an organism as landmarks on a digitized image. These are then superimposed on a standard grid whereby each pixel of the image, including landmarks, now has a specific coordinate. Each coordinate includes all the information about its relative position to all of the other coordinates, negating numerous separate (and complex) measurements between features. This system removes confounding variables such as location, scale, and rotational effects, leaving just data on the shape of the organism. With a landmark system, deformation caused by lithification or from metamorphic alteration can be corrected for. This process is much more complex than simpler and more often used methods but, it removes a considerable amount of error allowing for an improved analysis of how *Pteridinium*'s morphology might be altered.

*Pteridinium* (as most Ediacarans fossils are) was a difficult subject for landmark placement as the only repeatable features on the fossil is the central seam (fig 2). The reason for the quilts gentle curves have been hypothesized to result from deformation, mainly, but there has been evidence that it could also arise as a true function of its living (original) shape; it was for these reasons that landmarks placed along these quilts were designated as secondary and weighted differently in the analyses using statistical calculations. Standard grids were not capable of placing secondary landmarks in a uniform manner so a radial grid was employed with much success (see fig 3).

#### **Field Experience**

This project started off with a trip to the Yale Peabody Museum at Yale University in the fall of 2007 to take measurements from their extensive Ediacaran collections. Discussions with Dolf Seilacher, a leader in the Ediacaran field, helped with finding contacts in Namibia. The following summer in July of 2008 I headed to Windhoek, Namibia to take measurements at their National Museum's collections, one of the largest collections of *Pteridinium* in the world (fig 4). A little over a week was spent working in their collections. This included a few days in the beginning collecting the

proper lighting and stands for the specimens while also selecting which specimens could actually be used since there needed to be a fair amount of preservation to use morphological analyses.

The next few days were spent traveling south to the Town of Aus to meet the owner of Farm Aar [Lat: 26°40'35.37"S, Long: 16°31'51.81"E] (fig 5), Bruno Ernie, the actual collection site of most of the museum's specimens. For the next week there was a blur of collection measurements (the Farm has a private collection separate of the National Museum's due to space issues) and field measurements. Some of the initial results of this study were presented at the 33<sup>rd</sup> International Geologic Congress in Oslo, Norway in early August of 2008, following the trip to Namibia, during a section of talks devoted entirely to the Neoproterozoic. That August, only a few weeks after returning from abroad I visited both Jacksonville, Florida and Raleigh, North Carolina to research the North Carolina *Pteridinium* specimens. Gail Gibson, one of the two original discoverers of the North Carolina Ediacaran fossils, allowed me access to his collection as did the invertebrate division (most notably Patricia Weaver) of the North Carolina Museum of Natural History in Raleigh, NC.

### **Results**

The funds given for this research by the American Philosophical Society have been of great use and I am very appreciative that this project was accepted for funding. The research your funds allowed has led to many exciting discoveries in our understanding of early complex (multicellular). One of the more interesting finds is that the growth of *Pteridinium* (by the addition of quilts to the ends of the organism), in any location, is essentially random (see fig 1b). Much like certain sea shells coil to the left or right, so does the growth pattern of *Pteridinium*, but unlike gastropods whose coil direction is set in each species, *Pteridinium* doesn't distinguish coil direction around its central axis/seam. This had been found in the Namibian fossils prior to this research, but it has never been applied to any other locality or fossil population. These results are provocative in their enigmatic nature. We are still uncertain of the biological affinities of *Pteridinium* and the seeming lack of growth organization is something that is not found in modern multicellular organisms. More research is needed and is being undertaken to help solve this problem.

In the hypothesis there was an emphasis on change in time, but due to costs of permits and collection unavailability the Russian samples that were intended to add a third data point, in a temporal sense, could not be studied. Given this difficulty there still has been significant strides in understanding how different lithologies affect these fossils' structure and preservation, life habits, and population differences. The North Carolina specimens have never undergone any statistical tests since their discovery, and have little study in general in the last 10 years in comparison to other known major Ediacaran locales; the Namibian specimens have not been subject to geometric morphometric statistical techniques. They have been listed as different species only due to their different apparent shapes and current locations, though 540 mya they would have only been within a couple hundred miles of each other in the same body of water. There is further confusion because, with the exception of North Carolina, these differing body types are often found at the same locale.

These, though, are just assumptions with no quantifiable evidence behind them, which is why geometric morphometrics is so valuable; it allows investigation on the

degree of relatedness and the type of differences (disparity) each group exhibits when compared to one another. The sampling technique used allowed for specimens to be sampled multiple times to test whether deformed specimens would alter identification. After inputting their morphological data into a number of Principle Components and Canonical Variants analyses it was found that these two groups are closely related (fig 6), but still different enough to be separate species. Even the Namibian specimens that have been categorized as the North Carolina species cluster well within the Namibian group.

While the differences between the two groups could be attributed to different current properties in different environments, but the statistical data represented doesn't agree with that hypothesis. The Namibian specimens are from a broad delta environment with a sandy substrate that allowed for anchoring while the North Carolina specimens are from a continental slope with a steady, rapid current and much finer, clayey sediment that is poor for anchoring. Simple current differences would allow for the disparity in quilt curvature and outline shape of these organisms if these groups were only morphologically modified versions of the same organism (think of the numerous domestic dog types, they look different, but are the same species *Canis familiaris*). However, the differences in the central seam attachments, quilt widths, and how those quilts deform as you move away from the center of the organism firmly denote a separate species that is adapted for a different habitat. This is the most unequivocal evidence that the curvature in *Pteridinium*'s quilts are indicative of life pose and are not caused by deformation or process involved in lithification.

#### **Future Research**

Some of the initial results of this study were presented at the 33<sup>rd</sup> International Geologic Congress in Oslo, Norway in early August of 2008 during a section of talks devoted entirely to the Neoproterozoic. Due in part to talks at that conference, and discussions with prominent scientists throughout the course of this study, there are numerous plans to expand the scope of this research. I have secured a doctoral position at Virginia Polytechnic in Blacksburg, Virginia with Shuhai Xiao, one of the world's leading Ediacaran researchers, which will allow greater access to current trends and study in the field. I will be meeting with the original discoverers of the North Carolina Ediacaran fossils in June 2009 to complete the writing of two NSA proposals that will incorporate new research gains in the regions with high school science education. I have also been invited to join an Australian research team from Monash University back at Farm Aar in November 2009.

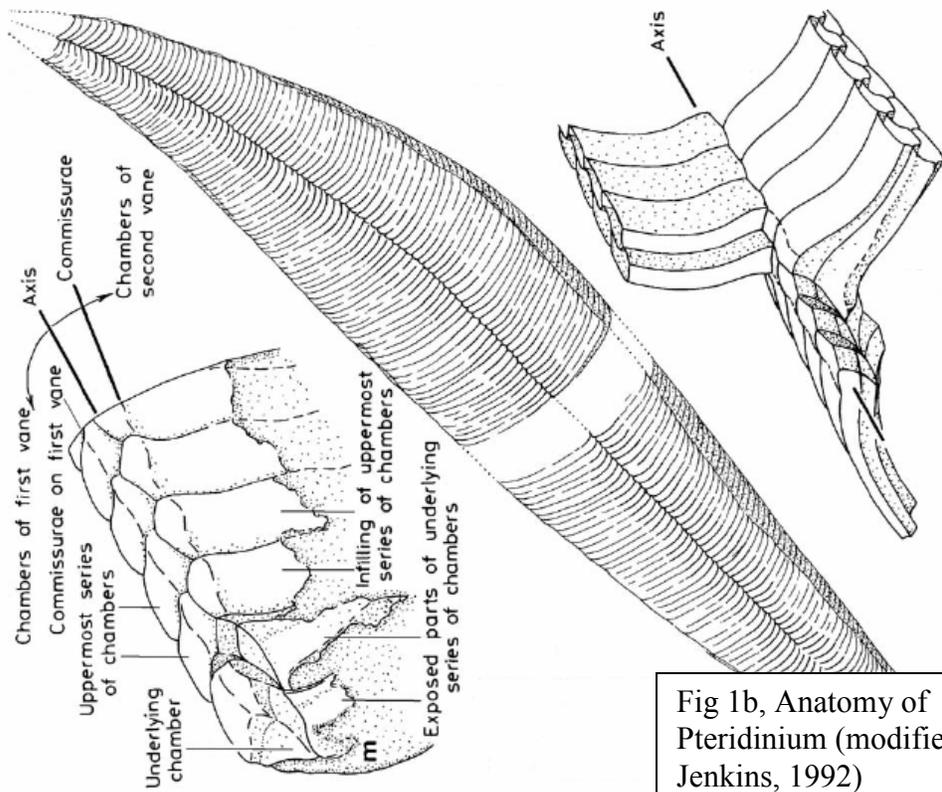
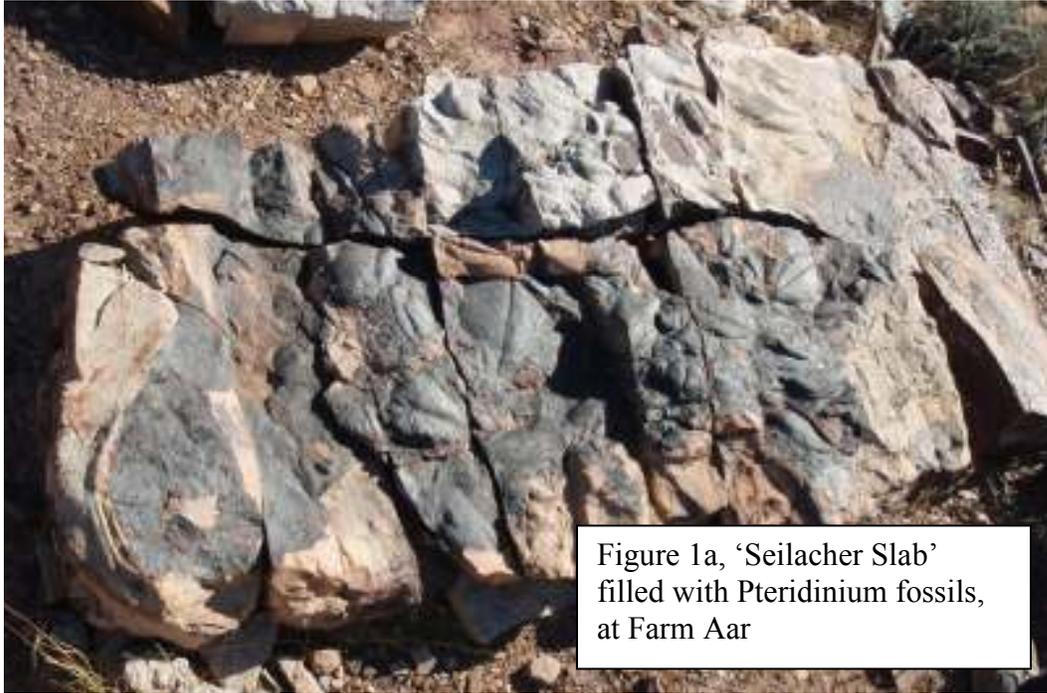


Fig 1b, Anatomy of Pteridinium (modified from Jenkins, 1992)

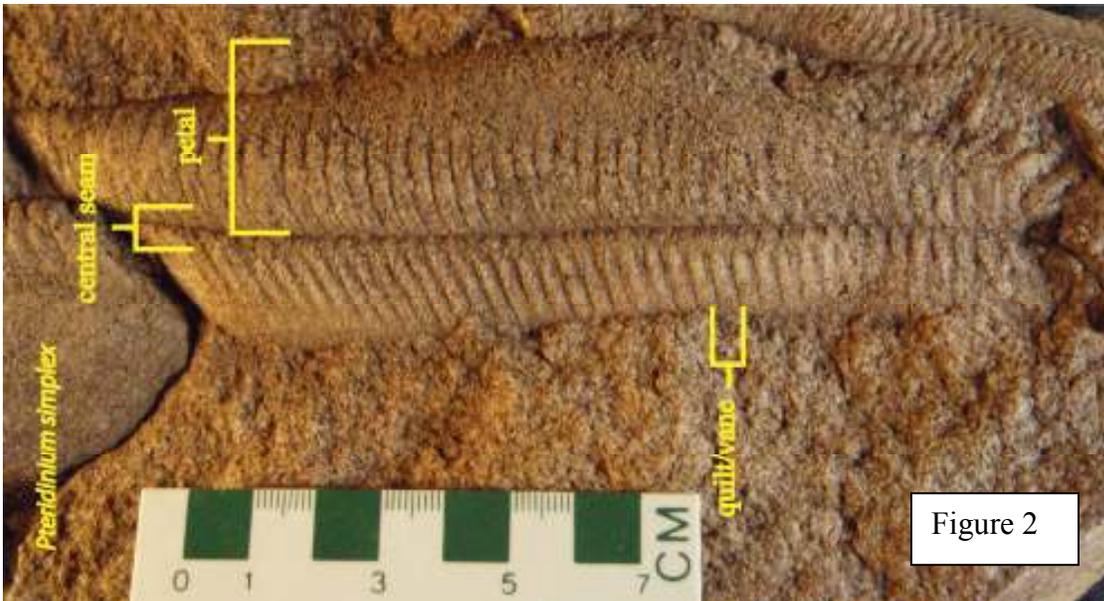


Figure 2

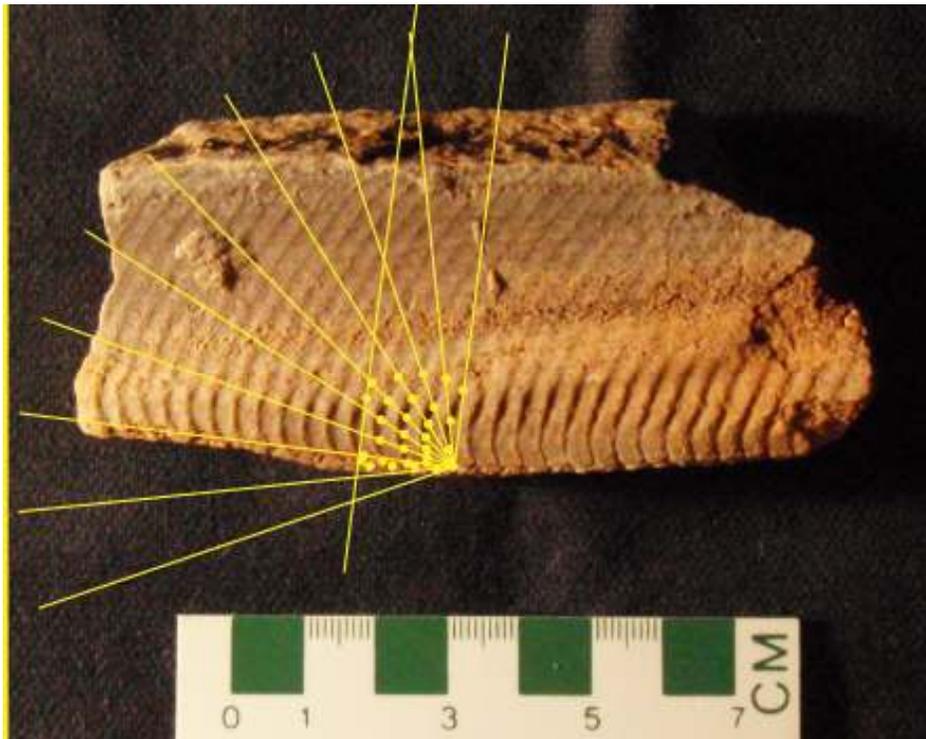


Figure 3 (above), Pteridinium under radial grid for morphological analysis.

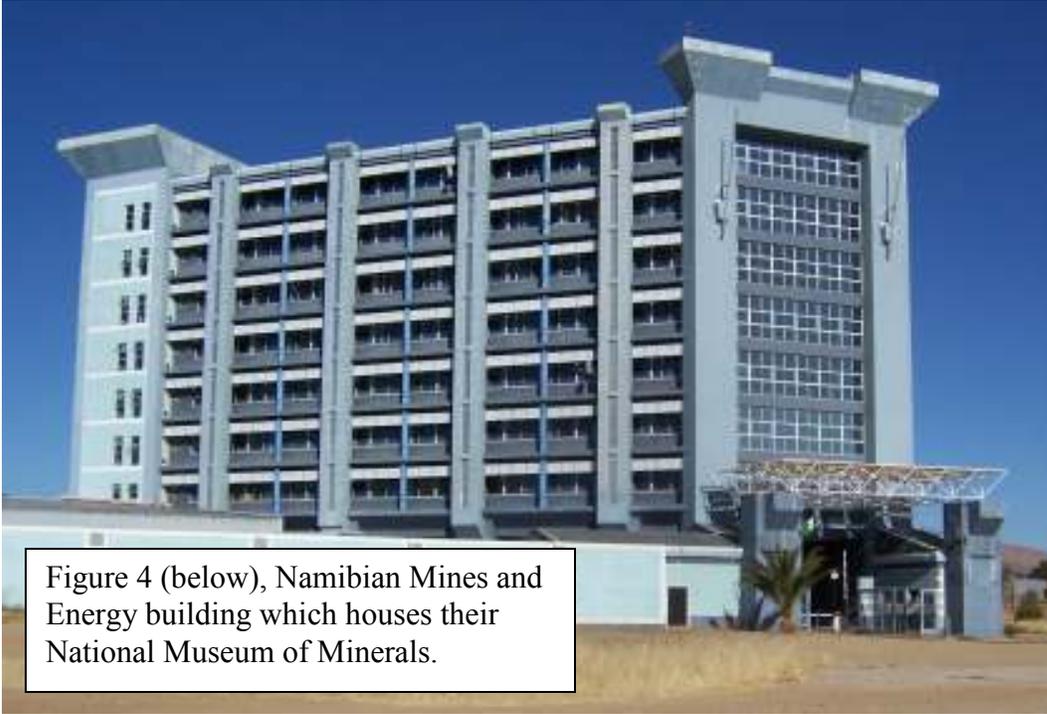


Figure 4 (below), Namibian Mines and Energy building which houses their National Museum of Minerals.



Figure 5, Farm Aar field site.

Figure 6, Canonical Variants Analysis showing the two groups of samples.

